THE FAUNA OF ROCK BOTTOM PONDS.*

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INTRODUCTION.

This investigation was undertaken for the purpose of studying the fauna and also the physical changes in a series of rock bottom ponds successively greater in age. Although ponds of various types have been studied, either individually or with a view to determining the succession of life in a series of different ages, so far as I am aware no one has studied a group which originated on a substratum of bare rock.

The ponds in question are in a number of limestone quarries near Sandusky, Ohio. Within a radius of fifteen miles there is a series of five ponds which at the time of the investigation were one, five, ten, fifteen and thirty years old respectively. They were formed as the result of striking water in the course of

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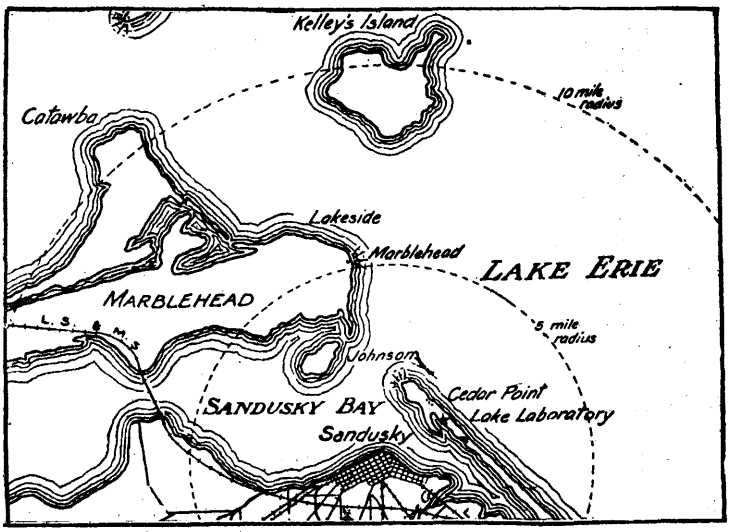
quarrying operations. The thirty year pond is in the grounds of the Soldiers' Home on the southern outskirts of Sandusky. The two-year and the ten-year ponds are about half a mile beyond this and within one hundred yards of each other. The five-year pond is about five miles from Sandusky on Marblehead peninsula and within one hundred yards of Lake Erie. The fifteen-year pond is on Kelley's Island approximately twelve miles from Sandusky and four miles off shore in Lake Erie. The relative location of the series can be seen by referring to the map of the region on this page.



Map of the Region.

These ponds were under observation for four summers but the detailed work on which this article is based was done during the summers of 1916 and 1917. The seasonal succession is, therefore, not considered. However, summer is the season when in general the animals of a given habitat are most in evidence and the results given here are in all likelihood thoroughly representative.

In studying a given pond it was first examined as a whole and then certain definitely delimited areas typical of its various environments were studied intensively. In order to gain a concrete idea of the abundance of a given species all individuals taken in certain small areas were counted. Because of difficulties with

the more active individuals these numbers are not absolutely accurate in all cases. They are a fairly close approximation, however, and are given in the belief that they serve to present a better idea of numbers than the terms "scarce," "common," "abundant," "numerous" and "few" which are relative and depend largely on the individual using them. For various reasons it was not possible to carry out this method at all times. When it had to be omitted numbers have either been indicated by the more relative method or they have been left out entirely. For determining the numerical quantity of plankton species, five samples were taken out of the total quantity derived from 100 liters of water and a count was made from each sample with the Sedgewick-Rafter cell.

The apparatus and methods used in collecting do not require extensive mention. A convenient field outfit for determining carbon dioxide was loaned by Prof. Foulk of Ohio State University. To determine the transparency of the water a porcelain lined top from an ordinary glass fruit jar was used. A simple dredge and several small nets were constantly needed.

In plankton collection tow nets were used when merely a sample was desired. These nets were maintained at a given level, whether at the surface or any number of feet below the surface, by means of a float which consisted of a small, tightly closed tin can. For quantitative plankton work a small hand pump of the type frequently employed in spraying was used. One method of operation was to pump water into a vessel of known capacity and then empty this into a net which was suspended in the pond. Another way was to pump directly into the net suspended in a vessel filled with water. The water then flowed from this into a vessel of known capacity. The first method seemed to give more accurate results for, unless the stream of water from the pump issued with very little force, some plankton forms were driven through the net. Either of these methods makes it possible to measure the exact amount of water passing through the net and avoids the possible error which may arise in the use of a plankton net or even of a calibrated pump.

For obtaining water from levels several feet below the surface a garden hose was attached to the pump. White rings were painted on it at intervals of a foot to facilitate the determination of the depth at which the pumping was to be made.

A stone was tied to the end of the hose to prevent sagging. This stone was also so arranged that if water were to be pumped from the bottom, the stone was between the end of the hose and the bottom. In this way there was less likelihood of drawing up sediment.

In presenting the results of the survey I shall first of all take up the ponds separately and in the order of their age beginning with the youngest. This will then be followed by a more general comparison and discussion of the results.

I wish to thank Prof. Foulk for the use of apparatus and Prof. Barrows of Ohio State University for the identification of spiders I also desire to acknowledge my indebtedness to a number of students who have been of assistance to me. I am particularly grateful to my wife for her constant aid.

ONE YEAR POND.

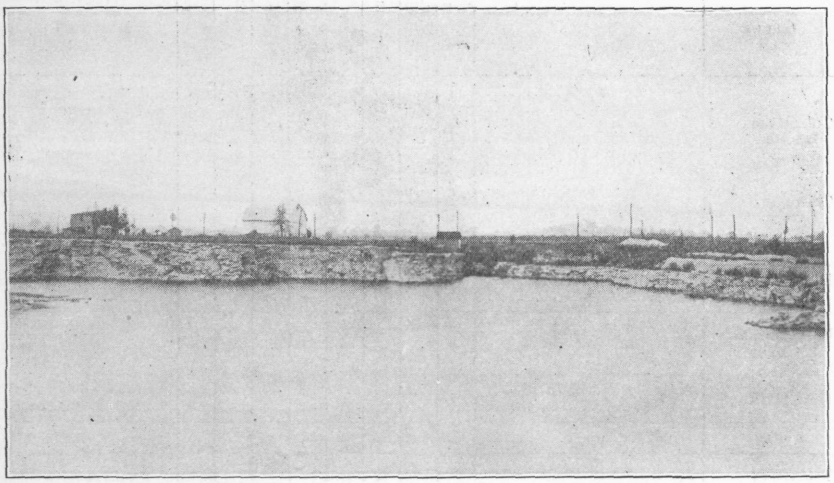
Pond I.

All of this pond was not, strictly speaking, only a year old since one corner of it covered a small pool in which water had collected while the quarry was still in operation. The greater part of it, however, was formed within a year of the time when it was examined. Taken as a whole it thus represents an extremely youthful stage in pond development. What might be termed the ancestral pool did not present a continuous habitat for aquatic forms since it was frequently emptied and was constantly kept under control by means of a steam pump.

Up to the autumn of 1916 the quarry was in active operation. It was then abandoned and by the summer of 1917 a pond 500 feet long and 150 feet wide had developed. Over most of it the water was from eighteen inches to three feet deep; over a restricted area it was as much as eight feet deep. The entire shore was of bare rock. On the east, west and north this rose up perpendicularly for 25 feet; along the south it rose 10 to 15 feet above the level of the water. The pond was surrounded on three sides by cultivated fields and on the fourth it was bordered by a gravel strip which intervened between it and an adjoining quarry. The photograph on page 431 gives an accurate idea of the pond and its surroundings.

The water was blue with a tinge of green. It was sufficiently transparent for the bottom to be seen anywhere. Its temperature just beneath the surface was 28° C. In the deepest water the bottom temperature was 26° C. In the shallower regions there was no difference between surface and bottom temperatures.

Vegetation was confined to filamentous algæ. These were everywhere abundant and usually extended to the bottom. Along most of the shore they were so thick as to form a dense mat on the surface. Decaying algæ were beginning to form organic sediment on the bottom which as yet was scarcely



Most of the One Year Pond is shown in this photograph.

measurable. There was approximately a quarter of an inch of inorganic sediment chiefly derived from the crushing of stone. Most of the larger stones had been cleared away but there were a few blocks at certain places. Details regarding these various features will be given in connection with the data from each of the stations.

STATION 1. This station covered a triangular bay enclosed by a rock wall ten to twenty feet high which sheltered it from all sides except the south. It is to be seen in the far corner of the photograph on this page. The water was from six to eight feet deep. Near shore, in shallow water, there were a few millimeters of sediment. In the center there were in places

three to four inches of rather mucky material which probably represented sediment from a wider area drawn together by the action of the drainage pump. Over this muck was a thick growth of *Chara* that had gained a foothold before the pond proper was formed. The accumulation of a sufficiently thick substratum for it to take root was undoubtedly hastened by the action of the pump. In with the ***Chara*** and reaching the surface were filamentous algæ.

The animals found at this station are given in Table 1.

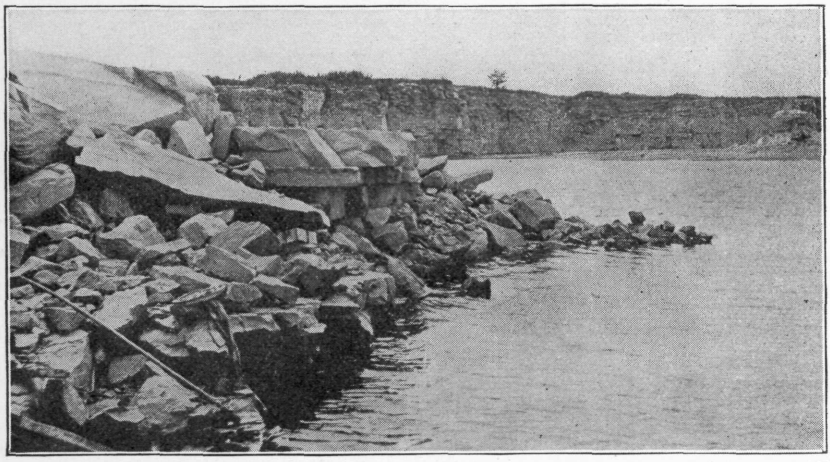
TABLE 1.

Group	Species	Littoral Stones	Sediment on Bottom	In Algæ	Chara	Mud of Chara Root	Nekton	Beneath Algæ	Surface of Water	Remarks
Coleoptera Adults	Hydroporus mixtus	1	..	..	..	..	..	..	..	
	Dineutes assimilis	..	..	..	..	..	..	..	3000	Area 5′ x 100′
	Gyrinus aquiris	..	..	..	..	..	..	..	..	
	Tropisternus nimbatus	1	..	..	..	..	..	..	..	
	Coelambus laccophilinus	1	..	2	..	..	..	..	..	Algae near edge.
Coleoptera Larvæ	Dytiscidæ	2	..	m'y	2	..	..	..	..	
	Gyrinidæ	1	..	..	..	..	..	..	..	
	Haliplidæ	1	..	2	1	..	..	..	..	
	Hydrophilidæ	..	..	5	..	..	..	..	..	
	Lagriidæ	..	..	..	2	..	..	..	..	
Diptera Larvæ	Corethra	..	100	..	..	..	..	..	..	
	Metriocnemus	..	..	50	..	..	..	..	..	
Ephemeridæ Nymphs	Amelitus sp	..	2	..	1	..	..	..	..	
	Heptagenia variabilis	x	..	..	..	..	..	..	..	
	Caenis allecta	..	..	..	2	..	..	..	..	
Hemiptera	Notonecta insulata	..	..	..	..	..	15	..	x	5 adults, 10 nymphs
	Corisa	..	..	..	..	..	x	..	5	1 adult, 4 nymphs.
Sialididæ	Sialid larva	..	..	..	2	..	..	..	..	
Tricoptera	Leptocerid larva	..	3	..	..	..	..	..	..	
	Hydrospyche sp(?)	..	..	1	..	..	..	..	..	
Crustacea	Asellus attenuatus	..	3	..	6	..	..	..	..	
	Cypris sp	..	..	..	..	x	..	..	..	
	Cyclops	..	..	..	..	..	..	..	..	
	Nauplius (Cyclops)	..	..	..	..	..	x	..	..	
Mollusca	Physa heterostropha	5	..	25	2	3	..	20	..	Beneath algæ, 1′x1′ 15 large, 5 small. In algæ, 4 large, 21 small.
	Lymnaea humilis	..	..	1	1	..	..	..	..	
	Planorbis parvus	..	..	..	3	..	..	..	..	
Annelida	Glossiphonia stagnalis	5	..	..	1	7	..	..	..	
Total number of species		9	4	8	11	3	2	1	3	

The figures in this table represent the number of individuals taken in an area 12 inches by 24 inches, except as otherwise indicated.

It will be seen from the table that, of the different habitats given, *Chara* had the greatest number of distinct species. The stones along the water's edge and the algæ floating free in the

water had, in turn, the next greatest number of inhabitants. The bottom and pelagic habitats had the fewest forms. The relative positions of the old and the young *Physæ* and also of the nymphal and adult *Notonecta* are interesting. As indicated in the table the young *Physæ* were almost exclusively on the filamentous algæ suspended in the water. On the other hand the older and larger individuals were chiefly on the semi-mucky material beneath the algæ. The nymphs of *Notonecta* were likewise in the algæ. They were most numerous in some which rested on a ledge about six inches below the surface. The leech, *Glossiphonia stagnalis*, was particularly abundant on *Chara*.



Station 2 of Pond I.

The gyrinid beetles were unusually numerous; one hundred of them were counted in a strip three inches wide and five feet long. In a strip five feet wide and one hundred feet long I estimated that there were 3,000. Most of those within the area covered by Station 1 were collected in this strip. It was noticeable that the beetles were not abundant over the main portion of the pond beyond the shelter afforded from strong breezes by the high walls enclosing the station.

STATION 2. The section of the quarry included in this station was not covered with water until within less than a year of the time it was studied. It is interesting because it was within 250 feet of Station 1, parts of which had been inter-

mittently submerged for a longer period. The photograph on page 433 indicates the character of the situation. It was typical of the conditions along the east side of the pond. The shore was perfectly bare rock. The water was between three and four feet deep and contained an abundant growth of algæ.

Table 2 presents a list of the species found in this region.

TABLE 2.

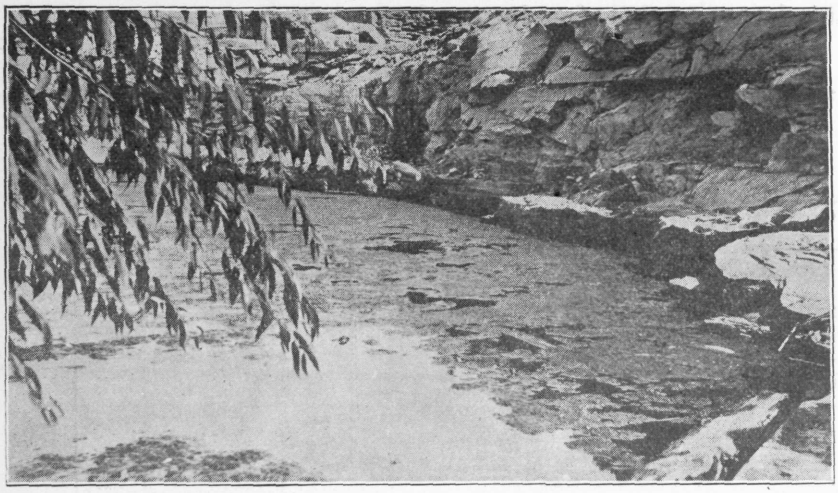
Group	Species	Algæ	Littoral Stones	Stones Beyond Littoral	Nekton	Surface Water	Sediment on Bottom
Coleoptera Adults	Hydroporus mixtus	....	x	....	....	....	....
	Hydroporus concinnus	....	x	....	....	....	....
	Agabus disintegratus	....	x	....	....	....	....
	Coelambus laccophilinus	....	x	....	....	....	....
	Dineutes assimilis	....	....	....	x	x	....
Coleoptera Larvæ	Dytiscidæ	x	x	x	....	....	....
	Gyrinidæ	....	....	x	....	....	....
	Hydrophilidæ	x	x	....	....	....	....
Diptera	Chironomus sp	....	....	....	....	....	x
Ephemeridæ	Heptagenia variabilis	....	x	x	....	....	....
Hemiptera	Notonecta insulata	....	....	....	x	x	....
	Corisa	....	....	....	x	x	....
Crustacea	Cyclops / Nauplius	....	....	....	x	....	....
Arachnida	Limnochares aquaticus	....	....	....	x	....	....
Mollusca	Lymnaea humilis	x	x	x	....	....	....
	Physa heterostropha	x	x	....	....	....	....
	Planorbis parvus	....	....	x	....	....	....
Annelida	Glossiphonia stagnalis	....	x	x	....	....	....
Total number of species		4	10	6	4	3	1

The total number of species for Station 2 is markedly fewer than it was at Station 1. There were no *Tricoptera* or *Sialididæ*. The species of coleopterous larvæ were fewer, although adult species were more numerous. Under the circumstances we would of course expect larval forms to be at least less common if not entirely absent. The mere fact that larvæ were present does not of necessity mean they had developed here from the egg, since they might have migrated from Station 1.

The greatest variety of species was found among stones in the littoral zone. At Station 1 this zone came next to the *Chara* in point of numbers, which were one less than at Station 2. No record was made at this station of the number of individuals for each species. However, two counts of *Physæ* were taken.

In one littoral situation, stony and with abundance of filamentous algæ, there were twenty-five *Physæ* in an area 6 x 4 x 5 inches. In another somewhat similar situation there were fifty-one in a space 2 x 5 x 3 inches. Most of them were young which was also true of those found in the algæ at Station 1. *Notonecta* were likewise common.

STATION 3. This was 500 hundred feet distant from Station 1 and covered that portion of the pond farthest away from the region of the original pool. It was one of the last portions to



Station 3 of Pond I.

be covered with water. The sides of the quarry rose up twenty-five feet and as elsewhere they were entirely devoid of vegetation. The conditions are shown in photograph above.

The water was not more than eighteen inches deep. In it there was a rich growth of filamentous algæ from bottom to surface. That on the surface formed a thick mat which in places extended twenty-five to thirty feet out from shore. It was more abundant here than anywhere else in the pond. On the bottom there was an inorganic sediment, chiefly quarry dust, one-eighth of an inch thick. Dead and decaying algæ were establishing the beginning of an organic deposit. In some places the partly decomposed algal material was a quarter of an inch thick. This amount, of course, would tend to diminish as decomposition became more complete.

The animals inhabiting the area are given in Table 3, below. There is a marked decrease in the number of species found here as compared with the list in Table 2. Most of the reductions come in the coleoptera; only two species of these were found, both of them adults. The absence of the surface beetles such as the gyrinids, so abundant at the opposite end of the pond, was noticeable and is apparently to be correlated with the great amount of filamentous algæ present, the mat it formed clearly making locomotion difficult. The *Notonecta* were also scarce and in this instance, likewise, the algæ probably offered a hindrance to their free locomotion.

TABLE 3.

Group	Species	Littoral	Algæ	Stones Beyond Littoral	Sediment on Bottom	Nekton
Coleoptera	Hydroporus mixtus	2	....	....	....	....
	Philhydrus ochraceus	4	....	....	....	....
Diptera Larvæ	Chironomus sp	....	....	....	50	....
	Tanypus sp	....	....	....	30	....
Ephemeridæ	Ephemerella excurcians	6	....	9	....	....
Hemiptera	Notonecta insulata	....	....	....	....	4
Crustacea	Cyclops	....	....	....	....	....
	Nauplius	....	....	....	....	x
Mollusca	Lymnaea humilis	5	3	....	....	....
	Planorbis parvus	1	2	2	....	....
	Physa heterostropha	5	23	34	....	....
Annelida	Glossiphonia stagnalis	1	....	1	....	....
Total number of species		7	3	4	2	1

The figures in the table refer to the number of individuals found in an area 12 by 18 inches.

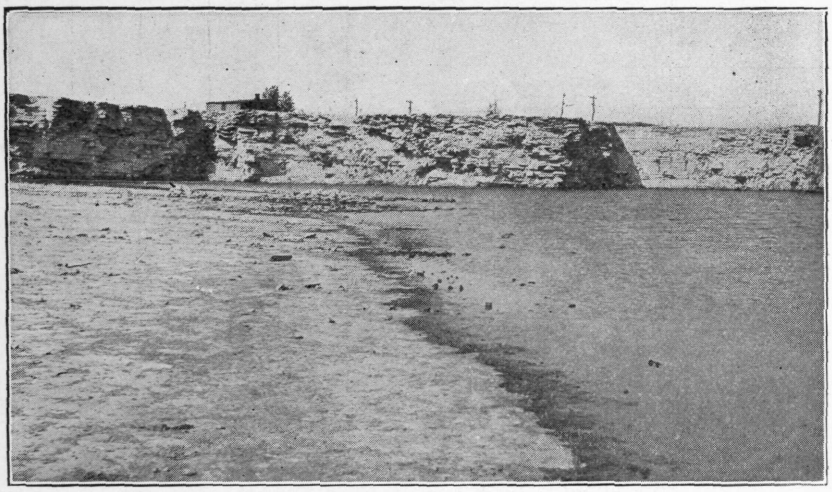
The thirty-four snails listed as coming from the stones beyond the littoral zone include some from the algæ. Here again the young snails were mostly in the algæ and the larger ones among the stones near the bottom.

Station 4. This station included the west side of the pond. It is shown on page 437. The floor of the quarry in this region gradually sloped beneath the water so that the depth of water was from a fraction of an inch along the edge to four or five inches fifty feet from shore. In the shallowest water there was practically no vegetation. In deeper water there were some filamentous algæ. On the bottom there were a few millimeters of organic sediment and also a few stones, most of them small.

The shallowest water offered a rather uncertain habitat, since even a very slight lowering of the general water level would lay the bottom bare, and, indeed, even without such an occurrence, the depth of water was hardly sufficient to accommodate any but the smallest animals.

The number of species found is the same as for Station 3 but the species differ. They are given in Table 4, page 438.

No general counts were made. On the whole, however, there were very few individuals of any one species. With the reduction in the amount of algæ, gyrinid beetles were again present where the water was deep enough for their maneuvers.



Station 4 of Pond I.

In the precarious littoral zone there were few species and also few individuals. In ten linear feet only five *Physæ* were observed and only one hybrobatid, *Gerris*, was seen in twice that distance. The scarcity of algæ was one reason for the comparatively few *Physæ*. Here and there patches of filamentous algæ were present and near these spots *Physæ* and also *Hydroporus* were noticed. I observed two or three sandpipers running along the water's edge. This bird was apparently quite a frequent visitor since its footprints were numerous.

PLANKTON. The plankton material taken in the summer of 1917 was accidentally destroyed. Material was again obtained in July, 1918. Although this does not represent conditions as

they were at the end of the first year, still it does represent an early stage in the plankton of a rock enclosed pond and for that reason I shall include it. The forms found most frequently are given in Table 5. The figures placed in line with each type represent, first the quantity in 100 liters of water and, following this, the percentage of the total catch which it represents. A glance at the table will show that any species not included were practically negligible so far as numbers are concerned.

TABLE 4.

Group	Species	Littoral	Stones Beyond Littoral	Algæ	Sediment on Bottom	Surface of Water
Coleoptera	Hydroporus mixtus	x	....	x	....	....
	Dineutes assimilis	....	....	....	....	x
	Gyrinus aquiris	....	....	....	....	x
Diptera Larvæ	Chironomus sp	....	x	....	x	....
	Tanypus sp	....	....	....	x	....
Ephmeridæ	Ephemerella excurcians larva	....	x	....	....	....
Hemiptera	Gerris conformis	....	....	....	....	x
Mollusca	Physa heterostropha	x	x	....	....	....
	Eggs of Physa	....	x	....	....	....
Annelida	Glossiphonia stagnalis	....	x	....	....	....
Vertebrata	Sandpiper	x	....	....	....	....
Total number of species		3	5	1	2	3

The figures for *Dinobryon* represent colonies. In addition to these there were a great many separated individuals which are not included in the count. The enormous number of colonies is interesting in view of the time of year at which they were obtained and the temperature of the water. They are ordinarily considered to be abundant in the cooler months of the year or, at least in cooler waters. This catch was taken in the middle of July from water of 28° C.

Discussion. Two prominent features of the association in this pond are (a) the entire absence of fish or any other aquatic vertebrate and (b) the preponderance of its insect population. The absence of fish was primarily due to the fact that none had yet been introduced by man. The large insect population was very probably correlated with the fact that no fish were present, especially so the great abundance of pelagic forms such as *Notonecta* and *Gyrinus*. The pond seemed to offer optimum con-

ditions for both of these species. In all the deeper regions the water was thickly populated with *Notonecta* from surface to bottom and in certain protected areas *Gyrinus* was equally numerous.

All of the species found in the pond are given in Table 6, page 440. A glance at the totals for each station will show that there was a progressive reduction in the number of the species as the distance from the parent pool, *i. e.*, Station 1, increased. This indicates a correlation between the age of the various parts of the pond and the number of inhabitants present. It also throws some light on the rate at which forms take possession of new and unoccupied habitats with which there is an unbroken medium of communication from a region already inhabited.

TABLE 5.

QUANTITATIVE PLANKTON RESULTS.

SPECIES	NUMBER PER 100 LITERS	PER CENT OF TOTAL
Ceratium	850,000	39.
Dinobryon	1,325,000	60.
Arcella	4,000	.0018
Rotifera	4,500	.002
Nauplius	15,625	.007

As might be expected the adult forms were more generally distributed than were the larval stages. This is especially noticeable with the coleoptera. Beyond Station 2 larval beetles were entirely absent. Among the diptera and ephemeridæ there was an uneven distribution of species. Larval representatives of these groups found at Station 1 were not present at Stations 2 and 3, and vice versa. Distribution of this sort is the result of entirely new colonization in the different localities and has no relation to migration within the pond.

In general, of the larger and more active or powerful adult forms in the region of the parent pool, seven out of eleven were found also at three or more of the four stations. Of similar forms present at only one or two stations there was an even division between those found at the parent pool and those that were not. Apparently, then, the adult population of the parent pool was well represented over the entire pond. The cases of localized distribution of adults were due to fresh colonization in the newer parts of the pond rather than to slow or capricious migration from the original pool.

There were two well defined instances of distribution being influenced by unlike food habits at different ages. One of these was shown by *Physa* which exhibited a very clear stratification and the other case was the relation of nymphal *Notonecta* and algæ. In this instance, however, there was no stratification.

TABLE 6.

Group	Species	Station 1	2	3	4
Coleoptera Adults	Hydroporus mixtus	x	x	x	x
	Hydroporus concinnus	..	x	..	..
	Tropisternus nimbatus	x	..	..	..
	Philhydrus ochraceus	..	..	x	..
	Dineutes assimilis	x	x	..	x
	Agabus disintegratus	..	x	..	..
	Coelambus laccophilinus	x	x	..	..
	Gyrinus aquiris	x	..	..	x
Coleoptera Larvæ	Dytiscidæ	x	x	..	..
	Gyrinidæ	x	x	..	..
	Hydrophilidæ	x	x	..	..
	Haliplidæ	x	..	..	..
	Lagriidæ	x	..	..	..
Diptera Larvæ	Corethra sp	x	..	..	..
	Metriocnemus sp	x	..	..	..
	Chironomus sp	..	x	x	x
	Tanypus sp	..	..	x	x
Ephemeridæ Nymphs	Heptagenia variabiis	x	x	..	x
	Amelitus sp	x	..	..	..
	Caenis allecta	x	..	..	..
	Ephemerella excurcians	..	..	x	x
Tricoptera	Leptocerid larva	x	..	..	..
	Hydrospyche sp?	x	..	..	..
Hemiptera	Notonecta insulata	x	x	x	..
	Corisa	x	x	..	..
	Gerris conformis	..	..	..	x
Sialididæ	Sialid larva	x	..	..	..
Arachnida	Limnochares aquaticus	..	x	..	..
	Pirata fibriculosa	x	..	..	..
Crustacea	Asellus attenuatus	x	..	..	..
	Cyclops sp	x	x	x	..
	Nauplius (Cyclops)	x	x	x	..
	Cypris sp	x	..	..	..
Mollusca	Physa heterostropha	x	x	x	x
	Eggs of Physa	..	..	..	x
	Lymnaea humilis	x	x	x	..
	Planorbis parvus	x	x	x	..
Annelida	Glossiphonia stagnalis	x	x	x	x
Vertebrata	Sandpiper	..	..	..	x
Total number of species		26	17	10	11

FIVE YEAR POND.

Pond II.

The five-year pond is on Marblehead peninsula,approximately one hundred yards from Lake Erie. It fills a rectangular depression in the solid rock of an abandoned quarry. This is the largest of the five ponds, its sides measuring 300, 250, 500 and 450 feet respectively. The quarry as a whole has been excavated from fifteen to twenty feet below the surface of the surrounding land. The pond is separated from the limits of

Station 1 of Pond II.

this excavation on three sides by a strip of quarry bed twenty-five to fifty feet wide. This was partly overgrown by grasses and weeds. On the remaining side the quarry bed stretches away for almost a hundred yards with only here and there a growth of vegetation. There are abandoned lime kilns at one point. In front of these the shore is made up of soft residue from the kilns. This is the only break in the solid rock enclosing the pond. In one corner the water extended out over this rock and formed several pools.

Most of the pond was between eight and nine feet deep with a maximum depth of thirteen feet and eight inches. The water was blue with a slight tinge of green. The transparency disk

was visible for nine feet and three and one-half inches. The temperature of the water just beneath the surface was 28° C. At a depth of five feet it was 27° C. and ten feet down it was 21° C.

STATION 1. The character of this station is shown on page 441. The side of the pond was a perpendicular face of practically bare rock. The water was between eight and nine feet deep. The only sign of vegetation was a sparse growth of filamentous algæ on the rock. On the bottom there was about one-fourth inch of sediment composed chiefly of quarry dust.

The species at this station are given in Table 7, below. The plankton and the nekton are not included, these being treated at another place for the whole pond. It will be seen that the number of forms was decidedly limited, although individuals were numerous in some cases as, for instance, the nematodes

TABLE 7.

GROUP	SPECIES	Algæ	Sediment	Bare Rock Bottom
Diptera Larvæ	Tanypus sp? Chironomus sp?	x x	.. ..	.. ..
Entomostraca	Cypridopsis vidua	..	x	..
Annelida	Nais elinguis	..	x	..
Nemathelminthes	Nematoda	..	x	..
Protozoa	Vorticella sp?	..	..	x

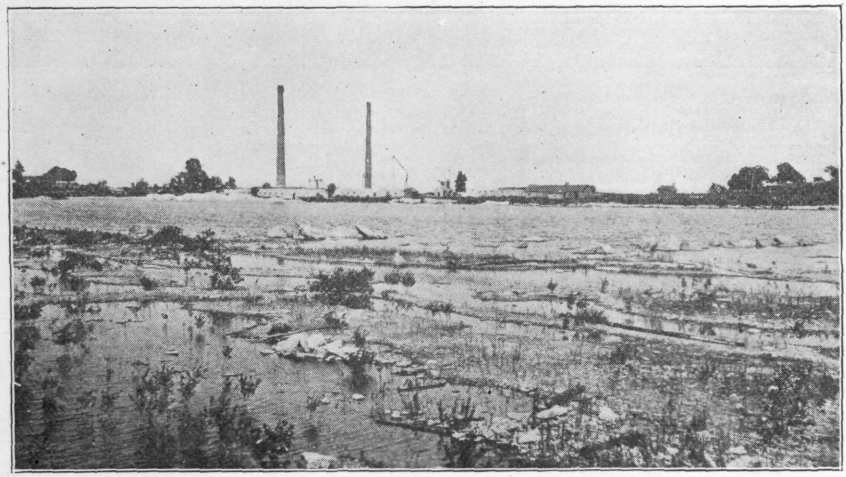
and the larvæ of the midges *Chironomus* and *Tanypus*. The entomostracan, *Cypridopsis vidua*, was also found in abundance. *Nais* was scarce and so was *Vorticella*.

This station was characteristic of three-fourths of the shore line in its physical features as well as in its animals and plants. A similar environment on the opposite side of the pond, the far side in the photograph on page 448, differed in that at places the water was not as deep and the bottom was covered with rubble. In such locations the nests of sunfish were observed.

STATION 2. The pools shown in the foreground of the photograph on page 443 comprise this station. Some of these were directly connected with the pond; others were formed by water seeping through the intervening gravel. They were all shallow,

the deepest having only five inches of water. A very slight change in the pond would obviously have wrought a great change in the pools. Unless otherwise indicated the conditions to be described will apply only to those pools directly connected with the pond.

The bottom was covered with pebbles, sand and chips of stone. The larger vegetation consisted chiefly of willow shoots. On the ridges between pools there was a miscellaneous scattering of grasses and weeds. Within the pools there were abundant growths of filamentous algæ.



Station 2 of Pond II.

Table 8, page 444, includes the forms from three pools. The species marked with an asterisk were all found in a pool broadly joined with the pond. Not all of these were in the other two pools.

Two-thirds of the snails were on the upper side of small stones. Most of them were young. They were far more abundant where algæ grew than they were on a bare substratum. In one pool containing algæ there were fifty-five *Physæ* in an area twelve by eighteen inches, whereas in a pool with practically no algæ there were only forty-five of them in an area seven feet by eighteen inches. Chironomid larvæ were present in great numbers. The Odonata were found near the edge of the pool among pebbles and sand.

STATION 3. This station covered the corner of the pond near the lime kilns. A portion of the shore is shown on page 445. A similar condition extended around to the right beyond the field of the picture. Refuse from the kilns had been dumped here and formed a substratum which, from an environmental standpoint, resembled a sandy beach. It was thoroughly soaked with water and in many places would not bear one's

TABLE 8.

GROUP	INDIVIDUAL	Stones Upper side	Stones Lower side	Pebbles and Sand	Surface of Water	Edge of Pool	Algæ	Nekton	REMARKS
Coleoptera Adults	Agabus disintegratus*	..	..	..	..	1	..	..	
	Gyrinus aquiris	..	..	..	1	..	..	..	In whole pond.
	Stenus sp	..	..	..	..	1	..	..	12″ x 18″
	Peltodytes sp., larva*	..	..	1	..	..	..	..	
Odonata Nymphs	Tetragoneuria cynosura*	..	..	4	..	..	..	..	
	Pachydiplax longipennis*	..	..	1	..	..	..	..	
	Anomalagrion sp.*	..	..	6	..	..	..	..	
	Ischnura sp	..	..	x	..	..	..	..	
Diptera Larvæ	Chironomus sp.*	179		..	..	..	..	..	
	Chironomus sp	16		..	..	..	..	..	12″ x 18″
	Tanypus sp	..	21	..	..	..	..	..	
Ephemeridæ Larvæ	Caenis allecta*	..	65	..	..	..	..	..	
	Heptagenia variabilis	..	x	..	..	..	..	..	
Hemiptera	Gerris conformis	..	..	..	x	..	..	..	
Tricoptera	Limnophilus sp.*	..	2	..	..	..	..	..	
Mollusca	Physa heterostropha*	x	x	x	..	..	x	..	
	Eggs of Physa	..	15	..	..	..	..	..	
Crustacea	Cypridopsis vidua	..	..	..	..	..	..	x	
	Cyclops ater	..	..	..	..	..	..	x	
Coelenterata	Hydra fusca*	..	3	..	..	..	..	..	
Vertebrata	Minnow	..	..	..	..	..	..	x	
	Tadpole (Rana)	..	..	..	..	..	..	x	
Total number of species		3	9	6	2	2	1	4	

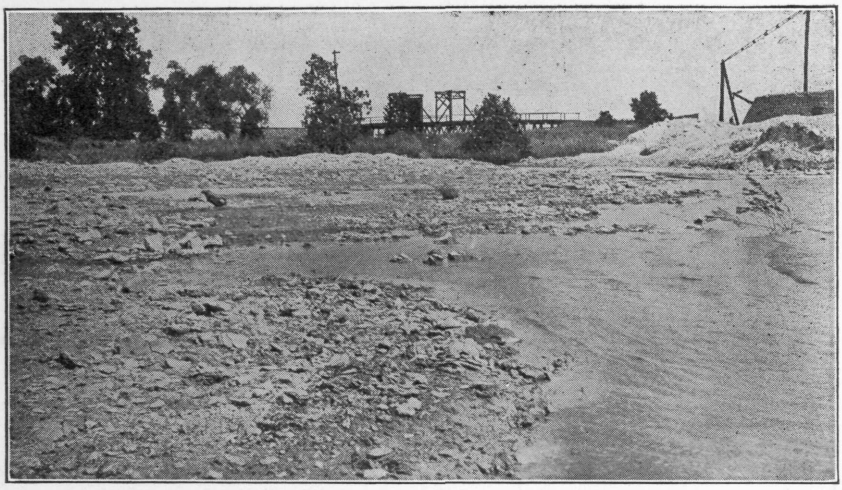
Numerals where given indicate the number of individuals in an area 7 by 12 feet, except as otherwise stated.

* See text for explanation of the asterisk.

weight. The water was shallow and the waves rasped the pebbles and finer particles about as sand is shifted by wave action. Such material is a very unsuitable habitat. The only vegetation consisted of the willow shoots and the bunch of grass shown in the photograph.

A few *Physæ* were scattered about where large stones gave them a firm footing. Here and there a few Chironomid larvæ were found and an occasional nymph of *Heptagenia variabilis*. Aside from these forms there were no animals in this area.

STATION 4. The fourth station covered an area representing conditions in the central region of the pond, beginning at least fifty feet from shore. The particular section studied in detail was about one hundred feet off shore, midway between Stations 1 and 3. Its location is shown approximately by the position of the boat in the photograph on page 448. About one-fourth of the entire bottom in this region was covered by a rather thick growth of *Chara* which grew in a substratum of mud formed from quarry dust. The maximum thickness of this mud was



Station 3 of Pond II.

three to four inches. The bottom over the rest of the pond had a fine, silty deposit one-fourth to one-half inch thick and was without vegetation.

The animals taken from the bottom were about the same as those in the bottom sediment of Station 1. A list of them is given in Table 9, page 446. Here again the nematodes were numerous. Blood worms were quite abundant. Larvæ of the midge, *Corethra*, were also found. *Nais* was more common than at Station 1. An occasional *Difflugia corona* was observed.

Fish were numerous all over the pond except in the shallow pools of Station 2 and in most of the area covered by Station 3, which was also shallow. From persons acquainted with the history of the pond I learned that some fish were introduced

not more than a year after the quarry filled with water. Bearing in mind the conditions in Pond I it is probably safe to assume that they found a large insect population to serve as a food supply. Other fish were thrown in from time to time. Nests present at the time of this survey afford good ground for concluding that the fish population has been continually increased by natural propagation.

TABLE 9.

Group	Species	Sediment	Chara mud	Nekton	Beneath Stones	Surface Tow	Deep Tow
Diptera Larvæ	Chironomus sp.	x	..	..	..	..	..
	Corethra sp.	..	x	..	..	..	..
Ephemeridæ	Heptagenia variabilis.	..	..	..	x	..	..
Entomostracan Crustacea	Cypridopsis vidua.	x	..	..	..	x	..
	Cypris sp.	x	..	..	..	..	..
	Bosmina longirostris.	..	..	..	..	x	x
	Daphnia sp.	..	..	..	..	x	..
	Chydorus sphaericus.	..	..	..	..	x	x
	Cyclops ater.	..	..	..	..	x	x
	Nauplius (cyclops).	..	..	..	..	x	x
Annelida	Nais elinguis.	x	..	..	..	..	..
Rotifera	Proales decipiens.	..	..	..	..	..	x
	Brachionus bakeri.	..	..	..	..	..	x
	Dystila ludwigii.	..	..	..	..	x	..
Nemathelminthes	Nematoda.	x	x	..	..	..	..
Protozoa	Ceratium longicorne.	..	..	..	..	x	x
	Difflugia corona.	..	..	..	..	..	x
	Arcella.	..	..	..	..	x	..
Vertebrata	Lepomis pallidus.	..	..	x	..	..	..
	Eupomotis gibbosus.	..	..	x	..	..	..
	Perca flavescens.	..	..	x	..	..	..
	Apomotis cyanellus.	..	..	x	..	..	..
Total Number of Species.		5	2	4	1	9	8

In order to gain an idea of what the fish were eating the stomachs of five were examined. Their contents is given below:

1. Lepomis pallidus
   - Mayfly nymphs, 3.
   - Filamentous algæ, small quantity.
2. Eupomotis gibbosus
   - Chironomus larvæ, 3.
   - Filamentous algæ, small quantity.
   - Beetles, 3; distinct species but undetermined.
3. Apomotis cyanellus
   - Tipulid larvæ, 8.
   - Ichneumon (?), adult 1.
   - Sialis larva, 1.
   - Blue-Green algæ, considerable.

	Dragon-fly nymph, 1.
4. Perca flavescens	May-fly nymph, 1. Blue-Green algæ, small amount.
	Chironomus larvæ, 4.
5. Apomotis cyanellus	Beetle, 1. Filamentous algæ, small amount.

PLANKTON. The plankton results are given in Table 10, on this page. This represents conditions two feet below the surface. The species of *Rotifera* which are listed separately in Table 9 have been grouped together in this table. Towings, taken over a period of two years in the course of class work, gave results which are a sufficiently close approximation to those given here to indicate that these afford a representative idea of plankton conditions during mid-summer.

TABLE 10.

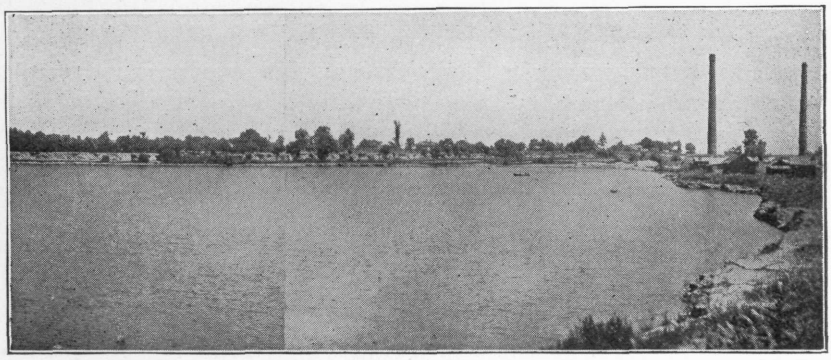
PLANKTON QUANTITATIVE RESULTS.

SPECIES	NUMBER IN 100 LITERS	PER CENT OF TOTAL
Ceratium longicorne	203,125	90
Nauplius	7,500	3.3
Chaedorus sphaericus	6,696	2.9
Arcella vulgaris	6,250	2.9
Rotifera	2,231	.9

DISCUSSION. A noteworthy feature of this pond is the almost total absence of insects from the greater part of it. In the list of all the forms, given in Table 11, page 449, no adult insects and only a few larval stages are credited to the deeper regions. Possibly at least a few representatives of the species named were present in these regions but they were at all events not noticeably common. In explanation of this state of affairs the fish must be considered. The pond was almost as thickly populated, proportionately, with fishes as was Pond I with *Notonecta* and gyrinids. The stomach contents of the fishes shows that a large part of their food was insects. The presence of appreciable numbers of insects in the shallow pools strikingly illustrates the faunal differences between waters that can be entered by fishes and those that can not.

Physical factors also had their influence on the character of the association. The smooth perpendicular face of rock offered a bleak and unattractive habitat for many animals normally

to be found along the shores of ponds. The shore-inhabiting coleoptera and the odonata nymphs found in the pool region frequent situations which furnish protection either in the form of small stones and debris or in the form of a yielding substratum. Much the same holds true for ephemerid nymphs and such snails as *Physa*. It will be noted that both of these were represented at Station 3 which is that part of the main pond approaching suitable conditions for them.



A view of the Five Year Pond.
The shallow pools are not visible.

A pond in the state of development attained by this one is thus seen to offer an environment primarily suited to pelagic forms, and the animals actually inhabiting it are largely of this type. The total absence of pelagic insects, as previously pointed out, is to be attributed to the fishes. However, when we consider all of the pond, both shallow and deep waters, insects far outnumbered any other class. This statement is perhaps not entirely fair to the protozoa, a careful tabulation of which was not attempted. Aside from these microscopic animals the insects composed forty per cent of the total population.

TABLE 11.

SUMMARY OF SPECIES IN FIVE YEAR POND.

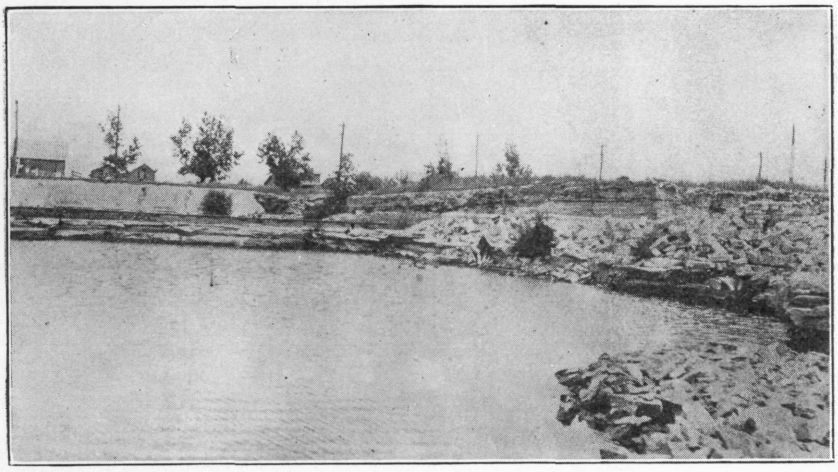
GROUP	SPECIES	STATION			
		1	2	3	4
Coleoptera	Agabus disintegratus*	..	x	..	..
	Gyrinus aquiris*	..	x	..	..
	Stenus sp.*	..	x	..	..
	Peltodytes, larva*	..	x	..	..
Odonata Nymphs	Tetragoneuria cynosura	..	x	..	..
	Pachydiplax longipennis*	..	x	..	..
	Anomalagrion sp.*	..	x	..	..
	Ischnura sp.*	..	x	..	..
Diptera Larvæ	Chironomus sp	x	x	x	..
	Tanypus sp	x	x	..	..
	Corethra sp	..	..	..	x
	Chironomus sp	..	x	x	x
Ephemeridæ Larvæ	Caenis allecta*	..	x	..	..
	Heptagenia variabilis	..	x	x	x
Hemiptera	Gerris conformis	..	x	..	..
Tricoptera	Limnophilus sp. larva	..	x	..	..
Entomostracan Crustacea	Cypridopsis vidua	x	x	..	x
	Cyclops ater	..	x	..	x
	Cypris sp	..	..	..	x
	Bosmina longiristris	..	..	..	x
	Daphnia sp	..	..	..	x
	Chydorus sphaericus	..	..	..	x
	Nauplius (cyclops)	..	..	..	x
Mollusca	Physa heterostropha	..	x	x	..
	Eggs of Physa	..	x	..	..
Annelida	Nais elinguis	x	..	..	x
Rotifera	Distyla ludwigii	..	..	..	x
	Brachionus bakeri	..	..	..	x
	Proales decipiens	..	..	..	x
Nemathelminthes	Nematode	x	..	..	x
Coelenterata	Hydra fusca	..	x	..	..
Protozoa	Vorticella sp	x	..	..	..
	Difflugia corona	..	..	..	x
	Ceratium longicorne	..	..	..	x
	Arcella sp	..	..	..	x
Vertebrata	Lepomis pallidus	..	..	..	x
	Eupomotis gibbosus	..	..	..	x
	Perca flavescens	..	..	..	x
	Apomotis cyanellus	..	..	..	x
	Minnow	..	x	..	..
	Tadpole (Rana)	..	x	..	..
Total number of species		6	22	4	22

* Species found only in region of pools.

TEN YEAR POND.

Pond III.

The ten-year pond is a rock-bound basin 140 feet long and 97 feet wide, in the bed of a quarry which is still being operated. It lies within three hundred feet of Pond I. It is surrounded on all sides by a desert of bare rock or finely crushed stone for distances of seventy-five feet to a hundred yards or more. By reason of this wide belt of bare territory this pond is probably more isolated than are the two just described.



Stations 1 and 2 of Pond III.

The water was between four and five feet deep, except for a small area where it was ten feet deep. This is about eighteen inches less than the depth sometimes attained. There was very little vegetation; two small willow trees and some rushes growing in a shallow stretch along one side. In the center of the pond there were thirty-two lily pads. None of these was seen before the summer of 1917. Except for such few traces of larger vegetation the pond presented a bleak appearance. Stones in the water were well coated with algæ, even at a depth of several feet. The bottom was covered with two to three inches of black silt composed of dust from the quarry and an admixture of decayed organic material from the pond itself.

The water was so turbid that the transparency disk disappeared two inches below the surface. This unusually low degree of transparency was due in large part to the great quantity of plankton, particularly the phytoplankton, which was so abundant as to make the water green. Tests failed to show any carbon dioxide either at the surface or at the bottom. The temperature of the water was 29° C. just below the surface; midway to the bottom and on the bottom it was 28° C.

STATION 1. The side of the pond at this point was a face of solid rock similar to that shown in the left background of the photograph on page 450. The water was two feet deep. A miscellaneous assortment of stones was scattered over the bottom. The forms found here were on these stones. A list of them is given in Table 12.

TABLE 12.

GROUP	SPECIES	COUNTS	REMARKS
Insecta			
Coleoptera	Hydroporus concinnus	2	Area 12″ x 18″. In algæ on rock.
Diptera Larvæ	Chironomus dux	50	Area 5 x 2 feet.
	Chironomus modestus	12	Surface area stones 4″ x 4″.
	Chironomus sp.		
Ephemeridæ Nymphs	Heptagenia variabilis	5	Area 4″ x 3″.
Tricoptera Larvæ	Polycentropus sp.	9	Surface area stones 4″ x 4″.
Mollusca	Physa heterostropha	6	Area 12″ x 18″.
	Eggs of Physa, masses	4	
Annelida	Glossiphonia nepheloidea	1	Entire station.
Coelenterata	Hydra fusca	..	

The *Physæ* were present down to the depth of a foot. The beetle *Hydroporus* was taken in the algæ along the water's edge. The numbers given for the various individuals were taken at random from several counts and represent average conditions. The numbers for the may-fly nymphs and the chironomid larvæ indicate the average abundance of these species, on stones of the size indicated, over the entire pond.

STATION 2. A pile of stones came to the surface at this point. The situation is shown in the left half of the photograph on page 450 just below the small bush. The animals found are given in Table 13. Except for the beetles they were all taken

below the surface of the water on stones. The beetles were running over the exposed portion of the stone pile near the water's edge.

TABLE 13.

Group	Species	Counts	Remarks
Coleoptera	Hydroporus concinnus Agabus disintegratus	1 2	Area 12″ x 18″.
Diptera Larvæ	Chironomus dux Chironomus sp Psychodid	15 ..	Area 4″ x 3″.
Ephemeridæ Nymphs	Blasturus sp Heptagenia variabilis	3 4	Area 4″ x 5″.
Tricoptera	Polycentropus sp	6	Area 4″ x 3″.
Mollusca	Physa heterostropha Egg masses of Physa	4 10	Area 12″ x 18″.
Annelida	Glossiphonia nepheloidea	2	

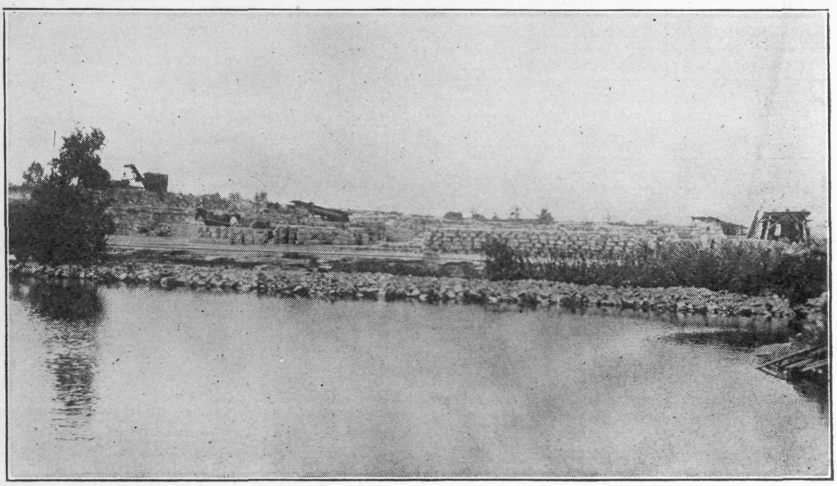
Station 3. Along the west side of the pond a pile of stones projected above the surface of the water. Among them there was a group of reeds. The conditions are shown on page 453. The animals named in Table 14 were taken in four to five inches of water from stones about the roots of the reeds.

TABLE 14.

Group	Species	Counts	Remarks
Diptera Larvæ	Chironomus sp Chironomus modestus	30 40	Area 7 x 4 feet. Area 2 x 4 feet.
Crustacea	Cypris sp Asellus attenuatus	.. ..	
Mollusca	Physa heterostropha Planorbis parvus	3 2	Area 12 x 18 inches.
Annelida	Glossiphonia stagnalis	2	
Vertebrata	Tadpole (Rana)	..	

Station 4. This covers the central area and also includes the plankton and the free swimming forms of the pond as a whole. As mentioned previously several lilies had become established in the center of the pond. Their roots were imbedded in three inches of silty mud. A list of the species is arranged in Table 15, page 454.

The fish were, of course, artificially introduced. The turbidity of the water made it impossible to see them and thus gain even an approximate idea of how many there were. Their numbers were probably not great, due both to the size of the pond and to the fact that the youngsters of the neighborhood caught them frequently. The general appearance of the pond did not leave the impression that it was a particularly suitable environment for fishes. However, so far as food was concerned there could have been little difficulty in view of the enormous amount



Station 3 of Pond III.

of insect life and the great quantity of algæ. The presence of young catfish and of hatching eggs showed that this species was able to propagate. There was no evidence of breeding on the part of the sunfish.

The stomachs of two sunfish and a catfish were examined. Their contents was as follows:

1. Eupomotis gibbosus	Ephemerid nymphs, 3. Chironomus larvæ, 2.
2. Ameiurus natalia	Shell of Physa. Ephemerid nymphs, 2. Algæ.
3. Eupomotis gibbosus	Ephemerid nymphs, 6. Algæ, considerable.

TABLE 15.

Group	Species	Lilly Leaves	Sediment	Nekton	Plankton	Surface of Water	Remarks
Hemiptera	Gerris conformis	..	..	..	..	x	Only one seen.
Entomostracan Crustacea	Diaptomus sp	..	..	..	x	..	
	Cyclops ater	..	..	..	x	..	
	Bosmina longirostris	..	..	..	x	..	
	Nauplius (cyclops)	..	..	..	x	..	
Rotifera	Cathypera luna	..	..	..	x	..	
	Triarthra longiseta	..	..	..	x	..	
	Rotifer neptunis	..	..	..	x	..	
Nemathelminthes	Nematode	..	x	..	..	..	
Mollusca	Ancylus shimeki	x	..	..	..	..	
Protozoa	Pleodorina sp	..	..	..	x	..	
	Ceratium longicorne	..	..	..	x	..	
	Chilomonas sp	..	..	..	x	..	
	Euglena viridis	..	..	..	x	..	
Vertebrata	Lepomis cyanellus	..	..	x	..	..	
	Ameiurus natalis	..	..	x	..	..	
	Eggs of catfish	..	..	..	..	..	
Algæ	Merismopaedia	..	..	..	x	..	
	Pediastrum	..	..	..	x	..	
	Scenedesmus	..	..	..	x	..	
Total number of species		1	1	2	14	1	

PLANKTON. The plankton catch was taken within a foot of the surface. The quantitative results are given in Table 16. It will be seen that the blue-green algæ comprised by far the greatest part of the catch. This abundance is not a casual occurrence. Sample towings taken in other years offer ample evidence of similarly large quantities of algæ. The figures given in the table have reference to the number of algal filaments.

TABLE 16.

PLANKTON QUANTITATIVE RESULTS.

Species	Number in 100 Liters	Per Cent of Total
Blue-green algæ	685,250	80.
Pleodorina	67,000	7.9
Nauplius	55,800	6.5
Pediastrum	17,850	2.1
Ceratium	11,160	1.3
Rotifera	10,892	1.2

DISCUSSION. All of the animals inhabiting the pond and the types of environment in which each was found are given in Table 17, page 455. About one-third of the total number of

species were insects. The other inhabitants were rather evenly distributed through five groups. In these groups plankton and pelagic types were by far the most numerous.

TABLE 17.

SUMMARY OF SPECIES IN TEN YEAR POND.

GROUP	SPECIES	STATION			
		1	2	3	4
Coleoptera	Hydroporus concinnus	x	x	..	..
	Agabus disintegratus	..	x	..	..
Diptera larvæ	Chironomus dux	x	x	..	..
	Chironomus modestus	x	..	x	..
	Psychodid	..	x	..	..
Ephemeridæ nymphs	Heptagenia variabilis	x	x	..	..
	Blasturus sp	..	x	..	..
Hemiptera	Gerris conformis	..	..	..	x
Tricoptera	Polycentropus sp	x	x	..	..
Entomostracan crustacea	Cypris sp	..	..	x	..
	Asellus attenuatus	..	..	x	..
	Diaptomus sp	..	..	..	x
	Cyclops ater	..	..	..	x
	Bosmina longirostris	..	..	..	x
	Nauplius (cyclops)	..	..	..	x
Mollusca	Physa heterostropha	x	x	x	..
	Planorbis parvus	..	..	x	..
	Ancylus shimeki	..	..	..	x
Annelida	Glossiphonia stagnalis	..	..	x	..
	Glossiphonia nepheloidea	x	x	..	..
Rotifera	Cathypera luna	..	..	..	x
	Triarthra longiseta	..	..	..	x
	Rotifera neptunis	..	..	..	x
Nemathelminthes	Nematode	..	..	..	x
Coelenterata	Hydra fusca	x	..	..	..
Protozoa	Pleodorina sp	..	..	..	x
	Ceratium longicorne	..	..	..	x
	Chilomonas sp	..	..	..	x
	Euglena viridis	..	..	..	x
Vertebrata	Lepomis cyanellus	..	..	..	x
	Ameiurus natalis	..	..	..	x
	Tadpole (Rana)	..	..	x	..
Algæ	Merismopedia	..	..	..	x
	Pediastrum	..	..	..	x
	Scenedesmus	..	..	..	x
Total number of species		8	9	7	19

The only forms which were well represented in point of numbers were the midges and the mayflies. Two factors are probably mainly responsible for the scarcity of other species. The fishes are the factor operating to reduce the pelagic insect population, whereas the almost total absence of vegetation and debris may be held accountable for the poor representation in other groups.

A comparative summary of counts, exclusive of the plankton, made at the various stations is arranged in Table 18, below. This shows a remarkably uniform density of population for a given species wherever it occurred, a condition which was most clearly and completely shown for the whole pond by one of the chironomid larvæ. The actual numbers given for Station 3 are twice as great as for either of the other two but it is to be noted

TABLE 18.

SUMMARY OF COUNTS.

	STATION		
	1	2	3
Chironomus dux and modestus	5 x 12 50		
Chironomus sp.	4 x 4 12	4 x 3 15	7 x 4 30
Chironomus sp.			2 x 4 40
Heptagenia variabilis	4 x 3 5	4 x 5 4	
Blasturus sp.		4 x 5 3	
Hydroporus concinnus	12 x 18 2	12 x 18 1	
Agabus distintegratus		12 x 18 2	
Polycentropus sp.	4 x 4 9	4 x 3 6	
Glossiphonia nepheloidea	Station 1	12 x 18 2	
Glossiphonia			Station 2
Physa heterostropha	12 x 18 6	12 x 18 4	12 x 18 3
Egg masses of Physa	18 x 18 4	12 x 18 10	
Planorbis parvus			12 x 18 2

that the area is also doubled. In the case of other insects, counts were obtained from two stations at most. The distribution of these was not quite as uniform as in the case of the chironomids. The leeches and snails were present in about the same numbers wherever they occurred but with nothing like the density of population shown by the larval insects. The pond as a whole was thus clearly more suited to the larval insects inhabiting it than to the other macroscopic forms. As was to be

expected the plankton conditions were uniform throughout. I have no actual data on the fish distribution but I assume that the chief limiting factor would be extreme variation in the depth of the water. Apparently, then, the pond offered an almost equally suitable environment wherever a given species was found.

These counts give us data not only on the uniformity of distribution, but they also furnish some conception of the actual numbers which a pond of this comparatively small size can maintain. Assuming that the entire bottom was as thickly populated as the sample counts indicate the total number of the one species of chironomid larvæ would have been 2,444,400 and of the *Heptagenia* nymphs, 814,800. It is true that the muck covering much of the bottom offered an unsuitable habitat and was therefore, not as thickly populated but the above calculation is based on a surface in a single dimension only and when we consider that several thousand stones are equally populated on all sides the calculation is probably not far from the actual condition.

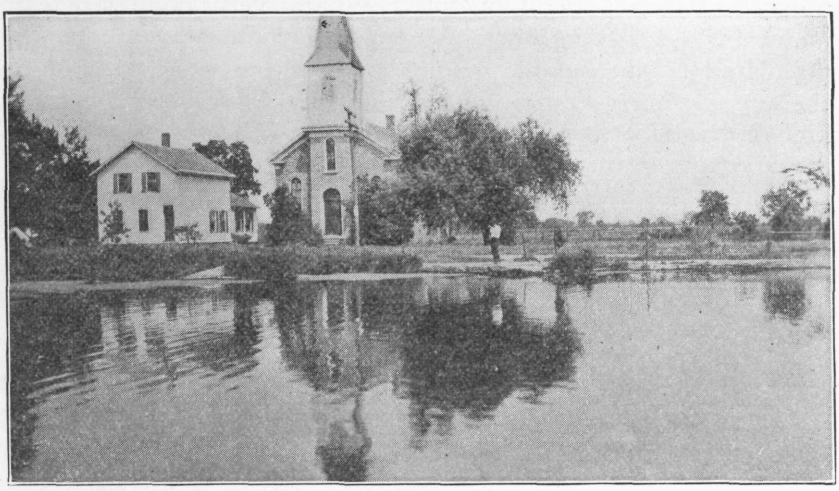
FIFTEEN YEAR POND.

Pond IV.

The fifteen-year pond is on Kelley's Island, Lake Erie, five miles off the Marblehead Peninsula. The entire island is a solid mass of rock covered by a thin layer of soil. The pond fills a shallow crescentic excavation in the rock, 100 by 150 feet in surface area. Along one side there is a public road, on another a lawn, and elsewhere a pasture. A portion of the pond is shown on page 458.

The depth of the water varied from eighteen inches to three feet with an indicated fluctuation of six inches. At each end of the pond, soil had slipped down to the water's edge and on this some willow bushes had become established. Here there was a foot or more of muck near shore which rapidly became less deep farther out. Mixed in with it was a miscellaneous collection of sticks, leaves and other debris. The surface of the water at one end was covered for several feet from shore with a thick mat of filamentous algæ. Narrow strips of this mat extended some distance down each side. The shore was chiefly bare

rock. Here and there a small bunch of willow shoots had obtained a foothold. The crevices and narrow ledges awash with the water were covered with algæ. Beyond the area of muck the amount of material on the bottom was at most three inches deep. In some places it was not more than an inch deep or barely that. This material consisted of dust from the road and of a considerable amount of decayed organic substance, chiefly algal.



Part of the Fifteen Year Pond.

The temperature of the water was 29° C. The water was kept more or less constantly stirred up by cows which frequently stood in one end of the pond. As a result it was so turbid that the transparency disk disappeared at six inches. The turbidity would have been great even had the cattle not been present by reason of the great abundance of the plankton algæ. These colored the water green. The cattle also made the water so foul as to give it a disagreeable odor. This was the only one of the ponds in such a condition.

The character of the pond was such that it did not seem necessary to divide it into stations. All the forms have been placed in a single table, Table 19, page 459. To the right, opposite each species there is indicated in a word, their relative abundance.

All of the species in this pond were also to be found in ponds on the mainland. There were no peculiarly island types. For most of the inhabitants in isolated ponds such as these in this series a few miles of water are probably no more of a barrier than as many miles of land. In fact it may be less of a barrier since it is an inhabitable medium.

TABLE 19.

Group	Species	Surface of Water	Muddy Shore	Algæ	Muck on Bottom	Nekton	Submerged Stones and Sticks	Remarks
Coleoptera adults	Gyrinus aquiris	x	..	..	..	x	..	Few
	Loxandrus sp	..	x	..	..	..	..	Numerous
	Hydroporus concinnus	..	x	..	..	..	..	Common
	Dytiscid (larva)	..	..	x	..	..	..	Scarce
Diptera larvæ	Chironomus sp	..	..	..	x	..	x	Numerous
	Larva, unidentified	..	..	..	x	..	x	Scarce
Ephemeridæ	Heptagenia variabilis	..	..	..	..	..	x	Few
Hemiptera	Gerris conformis	x	..	..	..	..	..	Few
	Notonecta insulata	x	..	..	..	x	..	Scarce
	Corisa sp	x	..	..	..	x	..	Scarce
Arachnida	Dolomedes sexapunctata	..	..	..	..	x	..	Scarce
Entomostracan Crustacea	Potamocypris sp	x	..	..	..	x	..	See Table 20
	Cypris inequivalva	..	..	..	..	x	..	
	Cypris sp	..	..	..	..	x	..	
	Diaptomus sp	..	..	..	..	x	..	
Mollusca	Lymnaea palustris	..	x	x	..	..	..	Common on mud
	Physa heterostropha	..	x	x	..	..	..	Numerous on mud
Annelida	Lumbriculus sp	..	..	x	..	..	..	Few
	Glossiphonia nepheloidea	..	..	..	..	..	x	Few
Rotifera	Rotifera neptunis	..	..	..	..	x	..	See Table 20
	Brachionus sp	..	..	..	..	x	..	
Protozoa	Ceratium longicorne	..	..	..	..	x	..	
	Arcella vulgaris	..	..	..	..	x	..	
Total number of species		5	4	4	2	12	4	

The catfishes were the only inhabitants that would have had to be introduced by human agency. The turtles were also probably introduced in this way but there is a possibility of their having migrated from the lake. Assuming that other fishes had been thrown into the pond, on which point I have no data, catfish were apparently the only fish that contrived to survive. Their young were numerous. Two physical factors probably operated against the survival of other fishes: (a) the quantity of silt, more or less constantly kept suspended in the water by the cattle; and (b) the foulness of the water also due to the cattle.

In connection with the absence of surface feeding fishes it is interesting to observe that the surface and pelagic insects such as *Notonecta*, *Corisa* and *Gyrinus* were present.

From the quantitative plankton table, Table 20, it will be seen that the phytoplankton made up by far the greater part of the entire plankton. The quantity of zooplankton was not large. All members of the zooplankton composed an approximately equal portion of it. Although *Potamocypris* was the least abundant of the plankton species, it was present in swarms that covered large patches of the surface. This abundance was merely a temporary matter since it is a species that is usually most in evidence during a few weeks only.

TABLE 20.

PLANKTON QUANTITATIVE RESULTS.

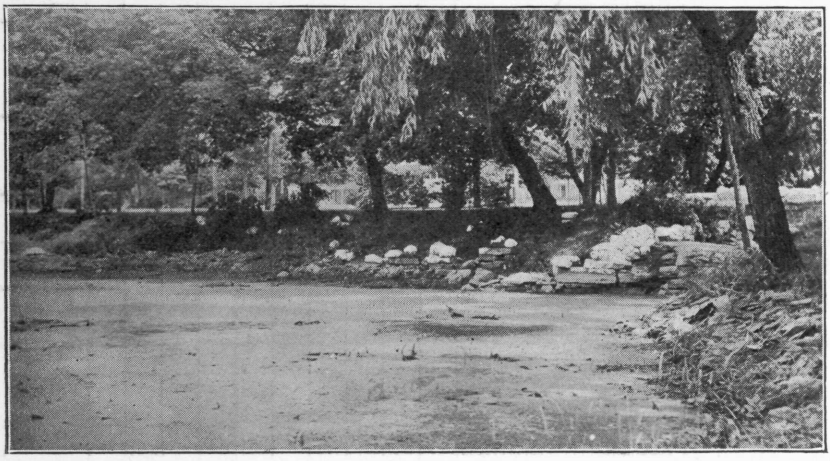
SPECIES	NUMBER IN 100 LITERS	PER CENT. OF TOTAL
Closterium	535,750	94.
Potamocypris	5,000	.878
Cypris inequivalva	5,890	1.03
Cypris sp	6,250	1.09
Rotifera	5,750	1.
Ceratium longicorne	5,250	.09
Arcella vulgaris	5,375	.09

THIRTY YEAR POND.

POND V.

In the grounds of the Soldiers' Home at Sandusky there is a group of three ponds supplied with water by a small stream from nearby springs. The ponds are at different levels and water passes successively from one to the other when there is enough of it to cause an overflow. At times the lower pond overflows and, by means of a ditch, connects with a creek about one-third of a mile distant. In the source of the water and in the occasional connection with the creek these ponds differ from the others included in this survey. These conditions may suggest that Pond V is not in a class with the others. The differences are not so vital, however, as they appear. The supplying stream, because of its own isolation and short extent, can have had little influence in introducing forms which would not otherwise have reached the ponds. The connection with the creek has been such an intermittent occurrence that any possible migration along this route must have been precarious.

Each of the three ponds was examined but attention was centered on the lower one. If there has been faunal contamination, so to speak, from the creek this pond would have been most effected, although once a form had migrated along the ditch to this point it could have gone on to the two upper ponds. The natural sequence of physical changes has apparently been least interfered with by man in the lower pond. Except for some masonry at one end to build a bridge and at the other to make an outlet, the conditions have taken a natural course.



A portion of the Thirty Year Pond.

The pond has an area of eighty by eighty-five feet. A portion of it is shown above. Its edges were still littered with the fragments of stone common about a quarry. Above these was a lawn and trees. The water was two to four feet deep, although this depth may vary as much as a foot from year to year. I have never seen it overflowing into the ditch. Its temperature was 29° C. The surface of the water has usually been well covered with *Lemna*. Beneath this, and distributed rather generally, there were filamentous algæ. From four inches to a foot of rich, black sediment, largely composed of decayed vegetation, covered the bottom. In this at several spots the pond lily, *Castalia tuberosa*, had taken root. Sticks and small branches were scattered about promiscuously. Along the edges there was a miscellaneous litter of leaves, sticks and

TABLE 21.

Group	Species	Surface of Water	Littoral Rocks	Surface of Muck	Algæ	Lilly Roots	Lilly Leaves & Stalks	Muck	Stones in Water	Plankton	Nekton	Remarks
Coleoptera adults	Hydroporus concinnus	..	..	..	x	..	..	..	..	..	..	Common
	Laccophilus maculosus	x	..	..	..	..	..	..	..	..	..	Few
	Agabus disintegratus	..	1	..	..	..	..	..	..	..	..	
	Philhydrus ochraceus	..	..	..	..	..	x	..	..	..	..	Few
	Loxandrus sp	..	..	2	..	..	..	..	..	..	..	
	Cnemidotus edentulus	..	..	..	x	..	..	..	..	..	..	Few
	Gyrinus aquiris	x	..	..	..	..	..	..	..	..	..	Scarce
	Stenus annularis	..	..	..	..	3	..	..	..	..	..	
	Dytiscid, larva	..	..	..	x	..	..	..	..	..	..	Few
Diptera larvæ	Tabanus sp	..	..	..	..	x	..	..	..	..	..	Scarce
	Chironomus sp	..	..	..	x	..	..	..	..	..	..	Few
	Chironomus sp	..	35	..	..	..	..	..	..	..	..	
	Metriocnemus sp	..	10	..	..	..	..	..	..	..	..	
	Ceratopogon sp	..	..	..	..	x	..	..	..	..	..	Few
Odonata nymphs	Sympetrum sp	..	..	..	2	..	..	..	..	..	..	
	Pachydiplax longipennis	..	..	..	..	..	1	..	..	..	..	
	Tetragoneuria cynosura	..	..	1	..	..	..	..	..	..	..	
	Anomalagrion sp	..	..	..	..	..	..	..	5	..	..	
Ephemeridæ nymphs	Caenis allecta	..	x	..	x	..	..	..	29	..	..	
	Heptagenia variabilis	..	15	..	..	..	..	..	x	..	..	
Hemiptera	Gerris conformis	x	..	..	..	..	..	..	..	..	..	Scarce
	Zaitha fluminea	..	3	..	..	..	..	..	..	..	..	
Crustacea	Aselus attenuatus	..	x	x	x	..	..	..	12	..	..	
	Cambarus virilis	..	3	..	..	..	..	..	..	..	..	
	Cypris inequivalva	..	..	..	..	..	..	..	..	x	..	
	Bosmina longirostris	..	..	..	..	..	..	..	..	x	..	
	Scapholebris sp	..	..	..	..	..	..	..	..	x	..	
	Ophryoxus sp	..	..	..	..	..	..	..	..	x	..	
	Ceriodaphnia sp	..	..	..	..	..	..	..	..	x	..	
	Potamocypris sp	..	..	..	..	..	..	..	..	x	..	
	Chydorus sphaericus	..	..	..	..	..	..	..	..	x	..	
	Nauplius	..	..	..	..	..	..	..	..	x	..	
Mollusca	Planorbis parvus	..	1	..	..	..	..	..	..	..	..	
	Physa heterostropha	..	43	..	x	..	..	..	..	..	..	
	Lymnaea humilis	..	..	x	..	..	..	..	..	..	..	
	Limax maximus	..	x	..	..	..	..	..	..	..	..	
	Pallifera sp	..	x	..	..	..	..	..	..	..	..	
Annelida	Glossiphonia stagnalis	..	..	..	..	..	..	..	4	..	..	
	Sparganophilus eiseni	..	..	..	..	..	..	x	..	..	..	Few
Rotifera	Brachionus bakeri	..	..	..	..	..	..	..	..	x	..	
	Aneuria cochlearis	..	..	..	..	..	..	..	..	..	..	
	var macrocantha	..	..	..	..	..	..	..	..	x	..	Numerous
	Aneuria cochlearis	..	..	..	..	..	..	..	..	x	..	
Plathelminthes	Planaria maculata	..	x	..	x	..	x	x	100	..	..	4″ x 5″
Protozoa	Difflugia corona	..	..	..	..	..	..	..	..	x	..	
	Ceratium longicorne	..	..	..	..	..	..	..	..	x	..	
Vertebrata	Lepomis pallidus	..	..	..	..	..	..	..	..	..	x	Few
	Ameiurus sp	..	..	..	..	..	..	..	..	..	x	Few
	Cyprinus carpio	..	..	..	..	..	..	..	..	..	x	Few
	Chrysemis marginata	..	..	..	..	..	..	..	..	..	x	Few
	Tadpole (Rana)	..	..	..	..	..	..	..	..	..	x	Few
Total number of species		3	13	4	9	3	3	2	6	13	5	

weeds. The physical conditions were everywhere so nearly uniform and the distribution of the inhabitants was so general that the pond has been treated as a unit.

It will be seen by a glance at Table 21, page 462, that most of the inhabitants, probably all of them except the fishes, are such as could have entered by natural means even though there had not been the partial connection with the creek. This connection may have made it easier for the crayfish (*Cambarus*), the snails (*Planorbis* and *Physa*), the leech (*Glossiphonia*), the annelid (*Sparganophilus*) and the planaria to have entered but all of these are to be found in entirely isolated bodies of water so that there is really no inhabitant, aside from the fishes, which would probably not have been present under isolated conditions.

The rich representation of insects is the outstanding feature, but the animal characteristic of the pond is a flatworm, *Planaria maculata*. It was teeming over every submerged solid object. I have never seen planaria so abundant anywhere. This condition was constant for the three summers over which my observations extended. The worms were about as numerous in the middle pond but they were decidedly less so in the upper one.

In connection with the insects it should be mentioned that while a number of species are represented, the number of individuals in all but a few species is small. The presence of such a variety of shore frequenting coleoptera is to be accounted for by the debris about the edges of the pond which afforded a suitable environment. Apparently the conditions were not especially suitable for breeding since the absence of coleopterous larvæ was markedly noticeable. The species of insects which were represented by numerous individuals all had larval stages in the pond also.

The isopod, *Asellus attenuatus*, was common everywhere, but was not noticeably abundant. The same can be said regarding the may-fly nymphs. *Glossiphonia* was more frequently seen on the lower stones nearest the muck.

The catfish and the carp are included on the authority of persons living near the pond. I did not see either species myself. The muddy nature of the bottom and the generally congested conditions appeared to offer a more favorable environment for either of these fishes than for the sunfish. The presence of surface feeding fishes is reflected by the almost total absence of surface and pelagic insects.

TABLE 22.

PLANKTON QUANTITATIVE RESULTS.

SPECIES	NUMBER IN 100 LITERS	PER CENT. OF TOTAL
Bosmina longirostris	6,300	36.4
Scapholebris sp	1,250	7.2
Ophryoxus sp	2,250	13.
Ceriodaphnia sp	2,250	13.
Potamocypris sp	1,000	5.7
Nauplius	2,250	13.
Brachionus bakeri	2,000	11.
Ceratium	Trace	
Arcella	Few	

The plankton in this pond was predominantly zooplankton. The quantitative results are given in Table 22. *Bosmina longirostris* was the species present in the greatest abundance. All the others were far less numerous.

GENERAL DISCUSSION OF THE SERIES.

PHYSICAL FEATURES.

A summary of the main physical features of the five ponds has been arranged in Table 23, page 465. It will be seen that there is a great difference in size between the largest and the smallest; the two younger ponds are from five to ten times larger than the three older ones. The latter are very nearly of a size. In harmony with the size differences there is a corresponding difference in temperatures; the larger bodies of water are a degree cooler than the smaller.

In a series of ponds such as we have here it is possible to gain some idea of the rate at which sediment accumulates. The amount of sediment which collects on the bottom of a pond as it increases with age is a matter of far reaching importance because of its influence on vegetation and on animal inhabitants. The rate at which this accumulation takes place is of value in determining the age of ponds whose past history is unknown.

The first of the two amounts indicating the depth of sediment for each of the ponds in Table 23 is the more accurate record of actual accumulation. The maximum depth of sediment in the one year and the five year ponds was in an area where the suction of a pump used in keeping the quarries dry had accumulated considerable material from over a wide region. In all

of the ponds there was an original layer of quarry dust which was from one-eighth to one-fourth inch thick. It is therefore safe to assume that the amount of organic material from the pond itself and of dust or other material from without which had accumulated on the bottom of the one year and five year ponds is negligible. A thick mat of algæ in the one year pond was furnishing a good source for such accumulations. The great amount of plankton in this pond during its second summer would also add to it.

TABLE 23.

Pond	Surface Area, sq. ft.	Depth, feet	Centigrade Temperature*	Transparency	Sediment		Vegetation	Environment
					Depth, Inches	Nature		
One year	(150x500) 75,000	1½–8	(26°) 28°	As depth	⅛–4	Silt (muck)	Algæ (chara)	Bare quarry bed. Cultivated fields.
Five year	(350x400) 140,000	¼–13¾	(21°) 28°	9′ 3½″	¼–4	Silt & muck	Algæ chara	Bare to sparsely covered quarry bed; cultivated fields.
Ten year	(97x140) 13,580	1½–10	(28°) 29°	10″	4	Black silty mud	Algæ Lilies Rushes	Bare quarry bed. Cultivated fields
Fifteen year	(100x150) 15,000	1½–3	(29°) 29°	6″	3–12	organic silt mud	Algæ	Pasture, lawn, road.
Thirty year	(85x80) 6,800	2–4	(28½°) 29°	2′ 6″	4–12	muck	Lilies Algæ	Lawn and shade trees.

*Temperature in parenthesis was taken at the bottom.

The rich plankton of the ten year pond must form a considerable layer of sediment each year. Added to this is undoubtedly quite an amount of material from the surrounding quarry the floor of which was quite dusty. The twelve inches of material recorded for the fifteen year pond was along one end where soil from above had slipped over the edges. Thick mats of algæ were evidently the chief source of organic deposit. In the thirty year pond the algal deposits were augmented by leaves from surrounding trees. The normal accumulation of this pond was increased by material washed down from the two ponds above it.

This series also furnish some data with regard to the rate at which rooted vegetation can become established on a substratum originally of rock. The five year pond had reached the point where it could support such vegetation in the form of

Chara. This is excluding from consideration the *Chara* in the year old pond since it became established in a pool antidating the present pond. Even for the *Chara* in the five year pond the substratum was artificially provided through the action of a pump. It should be noted in this connection that vegetation had already gained a footing about the five year pond, on the portion of the quarry bed not covered with water. It is therefore probable that the pond would have been able to support emergent vegetation if the water had not been so deep. As it is we find emergent vegetation, lilies and reeds, first appearing in the ten year pond. The irregularities of the situation are apparent, however, in the fact that the fifteen year pond had no rooted vegetation. This should be attributed to the cattle or to some other cause not connected with the substratum since parts of this pond offer a better foothold for vegetation than the ten year pond.

In considering the physical changes which have occurred it should be kept in mind that an important factor is the relative situation of the ponds with regard to sources of extraneous material. Ponds which are entirely surrounded by the bare bed of a quarry are not nearly so likely to be filled nor to undergo alterations along their shores as are those more closely surrounded by fields or trees. The ten year pond, for example, is in most physical features no farther advanced than the one a year old. The three younger ponds are so situated that by the time they attain the present age of the two older ones they will not have reached the present physical condition of the older ponds. The evidence from this series, then, is that the physical transformation which occurs in a rock bottom pond is not in proportion to age, at least during the first thirty years. However, this change, whatever its rate, causes such a pond to approach the condition of one established on a bottom of earth.

The Fauna.

The distribution of the various species through the five ponds of this series is summarized in Table 24, page 471. One of the interesting features brought out by the summary is the great number of species which are found in only one pond. Out of a total of 112 species for all ponds 65 species were present in but one pond, twenty-eight were in two, nine species were in three of them, four were present in four ponds and five species, also, were found in all of the ponds.

The cosmopolitan species were a chironomus larva, a water strider (*Gerris*), a may-fly (*Heptagenia*), a protozoan (*Ceratium*) and the snail *Physa*. Most of these are species which are to be found in almost any body of fresh water. In the distribution of the forms inhabiting but one pond we find them rather evenly scattered among all the ponds except the one fifteen years old. And so, too, with those present in two, three and four ponds respectively, there is an approximately even distribution of them through the series.

Practically all of these species are commonly found over a wide area. Their manner of distribution in these ponds, therefore, clearly shows that there may be great regional uniformity in the distribution of a species and, at the same time a local absence of uniformity even in habitats which, superficially at least, are apparently similar. The data given in connection with the respective ponds is sufficient to show that this condition can be traced in large part to the environment presented by each pond. To determine all of the factors in each case with any degree of completeness would take a much more detailed study extending over a greater period of time than I have been able to give the subject.

Regarding succession, it is hard to draw general conclusions because, over and above the natural sequence of environmental changes which is to be expected, each pond has a peculiar set of conditions which complicates the problem. However, a certain degree of faunal development is evident.

In the year old pond the following groups had become established: *Coleoptera* (larvæ and adults), *Diptera* (larvæ), *Ephemeridæ* (nymphs), *Hemiptera* (nymphs and adults), *Tricoptera* (larvæ), *Arachnida*, *Entomostraca*, *Mollusca* (snails), *Rotifera*, *Hirudinea*, *Protozoa*, and, if we exclude *Chara* as antidating the pond, filamentous algæ. The prominent faunal features in this pond are the great abundance of insects both in species and in individuals of certain species; also the fact that there were no vertebrates and, with two exceptions (*Arachnida* and *Mollusca*) fewer species of any other group than in any of the other ponds.

Insects composed twenty-seven out of forty-three species. There are both environmental and morphological reasons for this. Wings and flying as a means of locomotion enable insects to reach an isolated body of water before other forms which might

inhabit it but which are unable to reach it because of intervening obstacles. Further, once having reached it, adult insects can be semi-independent of a pond as a source of food. They can frequent it, even lay their eggs, and thus start an entirely aquatic fauna, and yet go elsewhere for their food. The absence of fishes, predaceous enemies of insects, is also an important factor. In point of numbers the aquatic insects *Notonecta*, *Corisa* and *Gyrinus* were by far the most abundant. Freedom from predaceous enemies permitted them to live and increase without hindrance. The influence of such enemies is clearly shown in a comparison of the one year with the five and the ten year pond. Both of the latter are well populated with fishes and in both, the strictly aquatic adult insects are entirely absent from the area which the fish can reach. The ten year pond is within a hundred yards of the one a year old and the five year pond is over six miles away. It is thus not a matter of location. In the fifteen year pond, on the other hand, the fishes are bottom feeders and here surface insects again appear.

The insect situation existing in these ponds does not agree with results found by Shelford* in a series with sandy bottoms. He states that aquatic insects are not numerous in the younger ponds but that they increase in the older with an increase in the vegetation. It should be noted, however, that in the youngest pond of his series there were ten species of fishes whereas in the oldest pond there were only four and these were not especially insectivorous.

The five year pond is primarily notable for the fact that fishes were firmly established. They were the dominating members of the fauna. Odonata nymphs had also become established. *Hydra* was observed here first and so, too, were nematoda and chætopod annelids. Over most of the pond there was no suitable environment for littoral animals. That the absence of such forms was not a matter of distribution is to be seen from the fact that at least some of these were present in pools at one side of the pond.

In the ten year pond emergent vegetation, lilies and reeds, had gained a footing. Along with this appeared a new type of mollusc, namely *Ancylus*. So far as my observations went the vegetation could not be correlated with the presence of any other species. The most abundant members of the fauna were chironomid larva and ephemerid nymphs.

* Animal Communities of Temperate North America.

The ten year and the one year ponds make an interesting comparison because of the fact that they lie side by side and both offer a bleak habitat. Their chief physical difference was in size. Faunally they differed most markedly in respect of their hemiptera, larval beetles, diptera and ephemeridæ. The two species of hemiptera so abundant in the one year pond were not in the ten year pond. The species of diptera and ephemeridæ were not the same in the two ponds. There were no larval beetles in the ten year pond. The absence of these is to be correlated with the greatly reduced number of adult species represented, as compared with the one year pond. In point of numbers the gyrinid and the dytiscid larvæ composed the larger part of all coleopterous larvæ in the one year pond. Adults of neither of these groups were in the ten year pond.

Several factors are probably responsible for the absence of the beetles from the ten year pond. The presence of fishes undoubtedly plays a large part. It is also to be noted that some of the species in the one year pond apparently prefer clear water. For example, Blatchley* states that *Philhydrus* rises to the surface when the water becomes turbid. The water in the ten year pond was decidedly turbid and this may therefore be a factor. Furthermore, there was little in the way of debris about the edges of this pond to attract the shore inhabiting species.

Two of the three species of ephemerid nymphs in the one year pond were not in any of the others. Their adults also were not numerous in the region. *Heptagenia*, the form in the ten year pond, was the most abundant member of this group in the region. Its chances for general distribution as a nymph were therefore greater and, as matter of fact, it was one of the types found in all of the ponds. Possibly the regional scarcity of the two species in the one year pond was a factor responsible for their absence from most members of the series.

In the fifteen year pond there were certain abnormal conditions which perhaps made it hardly a fair test of pond development at this age. It was the first pond offering conditions suitable for microdrilus oligocheta. This is said not merely because *Lumbriculus* was present but also because under the conditions it would have been surprising to have found them in the younger ponds. Turtles were seen for the first time and catfish also found a suitable environment.

*Coleoptera of Indiana.

This pond had the least number of species represented in its population. In view of its age and also of the fact that it presented a less barren environment than the three younger ponds, one could expect to find it inhabited with a greater variety of species. The island situation is one of the first reasons to suggest itself in explanation of this state of affairs. An examination of Table 24 will show that for most groups this pond compared favorably with the others in the number of species represented. Its non-flying population such as annelida, mollusca, etc., was about equal to that of the other ponds. In beetles it bore comparison with the five and the ten year ponds. The greatest loss in species came in the flying groups diptera, ephemeridæ and tricoptera. Isolation is hardly a satisfactory explanation for loss in representation among these species. It seems more probable that the condition of the water rendered the pond uninhabitable for larval members of some of the groups found in the other ponds.

The thirty year pond presented several new species. Strange as it may seem *Planaria* was found here for the first time. It was by far the most abundant member of the association. Crayfish also appeared here first and so did slugs and an annelid, *Sparganophilus*. This worm is to be found about the roots of aquatic plants in marshes and older ponds, although I have found it also along the pebbly and stony beach of a partly protected bay on Lake Erie.

The slugs, *Limax* and *Pallifera*, were both in moist situations under debris along the water's edge. The moisture and shade afforded them by the grass and trees in the surroundings would enable them to reach this situation without undue exposure to dry conditions. The only other pond with approximately similar surroundings was the one fifteen years old. All the others were bordered by a greater or less expanse of bare rock which presented desert conditions to any animal that would have attempted to migrate across it by crawling or creeping. In this respect the one, five and ten year ponds had an additional degree of isolation which undoubtedly prevented certain types of animals from reaching them. Until this bare expanse of rock is covered by vegetation it will continue to act as a barrier and thus aid in keeping the associations of the ponds in an ecologically younger condition.

The thirty year pond and the one a year old had almost the same number of insect species, but it will be noticed that, whereas in the youngest pond insects were abundant in both species and individuals, in the oldest pond they were abundant only in species. Furthermore, in the year old pond the species with the greatest number of individuals were represented either by pelagic adults or larval stages whereas in the thirty year pond most of the species are shore forms. Both ponds had the same number of species of adult beetles. Of the four present in the thirty year pond only, at least three are usually to be found among debris such as characterized the shore of this pond but not that of the younger one.

TABLE 24.

Group	Species	Ponds					
		1 Year	5 Year	10 Year	15 Year	30 Year	Total
Insecta							
Coleoptera adults	Hydroporus concinnus	x	..	x	x	x	4
	Hydroporus mixtus	x	..	..	..	..	1
	Tropisternus nimbatus	x	..	..	..	..	1
	Philhydrus ochraceus	x	..	..	..	x	2
	Dineutes assimilis	x	..	..	..	..	1
	Agabus disintegratus	x	x	x	..	x	4
	Coelambus laccophilinus	x	..	..	..	..	1
	Gyrinus aquiris	x	x	..	x	x	4
	Stenus sp	..	x	..	..	..	1
	Loxandrus sp	..	..	..	x	x	2
	Laccophilus maculosus	..	..	..	..	x	1
	Cnemidotus edentulus	..	..	..	..	x	1
	Stenus annularis	..	..	..	..	x	1
	Total adults	8	3	2	3	8	
Coleoptera larvæ	Peltodytes	..	x	..	..	..	1
	Dytiscidæ	x	..	..	x	x	3
	Gyrinidæ	x	..	..	..	..	1
	Hydrophilidæ	x	..	..	..	..	1
	Haliplidæ	x	..	..	..	..	1
	Lagriidæ	x	..	..	..	..	1
	Total larvæ	5	1	..	1	1	
Diptera larvæ	Tabanus sp	..	..	..	..	x	1
	Corethra sp	x	x	..	..	..	2
	Metriocnemus sp	x	..	..	..	x	2
	Tanypus sp	x	x	..	..	..	2
	Chironomus sp	x	x	x	x	x	5
	Chironomus dux	..	..	x	..	..	1
	Chironomus modestus	..	..	x	..	..	1
	Chironomus sp	..	x	..	..	x	2
	Psychodid	..	..	x	..	..	1
	Ceratopogon sp	..	..	..	..	x	1
	Total Diptera	4	4	4	1	5	
Odonata nymphs	Sympetrum sp	..	..	..	..	x	1
	Pachydiplax longipennis	..	x	..	..	x	2
	Tetragoneuria cynosura	..	x	..	..	x	2
	Anomalagrion sp	..	x	..	..	x	2
	Ischnura sp	..	x	..	..	..	1
	Total Odonata	..	4	..	..	4	

TABLE 24—(Continued).

Group	Species	Ponds					
		1 Year	5 Year	10 Year	15 Year	30 Year	Total
Ephemeridæ nymphs	Amelitus sp	x	..	..	..	..	1
	Caenis allecta	x	x	..	..	x	3
	Ephemerella excurcians	x	..	..	..	..	1
	Heptagenia variabilis	x	x	x	x	x	5
	Blasturus sp	..	..	x	..	..	1
	Total Ephemeridæ	4	2	2	1	2	
Hemiptera	Zaitha fluminea	..	..	..	..	x	1
	Gerris conformis	x	x	x	x	x	5
	Notonecta insulata	x	..	..	x	..	2
	Corisa	x	..	..	x	..	2
	Total Hemiptera	3	1	1	3	2	
Tricoptera larvæ	Leptocerid	x	..	..	..	..	1
	Hydropsyche sp	x	..	..	..	..	1
	Polycentropus	..	..	x	..	..	1
	Limnophilus	..	x	..	..	..	1
	Total Tricoptera	2	1	1	..	..	
Sialididæ	Sialid larva	x	..	..	..	..	1
Arachnida	Dolomedes sexapunctatus	..	..	..	x	..	1
	Pirata fibriculosa	x	..	..	..	..	1
	Limnochares aquaticus	x	..	..	..	..	1
	Total Arachnida	2	..	..	1	..	
Crustacea	Cypris inequivalva	..	..	..	x	x	2
	Cypris sp	x	x	x	x	..	4
	Asellus attenuatus	x	..	x	..	x	3
	Diaptomus sp	..	..	x	x	..	2
	Cyclops sp	x	..	x	..	..	2
	Cyclops ater	..	x	..	..	..	1
	Scapholebris sp	..	..	..	..	x	1
	Bosmina longirostris	..	x	x	..	x	3
	Ophryoxus sp	..	..	..	..	x	1
	Nauplius (cyclops)	x	x	x	..	x	4
	Cypridopsis vidua	..	x	..	..	..	1
	Daphnia sp	x	x	..	..	..	2
	Ceriodaphnia sp	..	..	..	..	x	1
	Chydorus sphaericus	..	x	..	..	x	2
	Potamocypris sp	..	..	..	x	x	2
	Cambarus virilis	..	..	..	..	x	1
	Total Crustacea	5	7	6	4	10	
Mollusca	Physa heterostropha	x	x	x	x	x	5
	Eggs of Physa	x	x	..	..	..	2
	Lymnaea humilis	x	..	..	..	x	2
	Ancylus shimeki	..	..	x	..	..	1
	Planorbis parvus	x	..	x	..	x	3
	Limax maximus	..	..	..	..	x	1
	Pallifera sp	..	..	..	..	x	1
	Lymnaea palustris	..	..	..	x	..	1
	Total Mollusca	4	2	3	2	5	
Annelida	Glossiphonia stagnalis	x	..	x	..	x	3
	Glossiphonia nepheloidea	..	..	x	x	..	2
	Sparganophilus eiseni	..	..	..	..	x	1
	Nais elinguis	..	x	..	..	..	1
	Lumbriculus sp	..	..	..	x	..	1
	Total Annelida	1	1	2	2	2	
Nemathelminthes	Nematode	..	x	x	..	..	2
Plathelminthes	Planaria	..	..	..	..	x	1
Coelenterata	Hydra fusca	..	x	x	..	..	2

TABLE 24—(Continued).

Group	Species	Ponds					
		1 Year	5 Year	10 Year	15 Year	30 Year	Total
Rotifera	Distyla ludwigii	..	x	..	..	..	1
	Aneuria cochlearis	..	..	..	..	x	1
	Aneuria cochlearis var. macrocantha	..	..	..	..	x	1
	Brachionus bakeri	..	x	..	..	x	2
	Proales decipiens	..	x	..	..	..	1
	Cathypera luna	..	..	x	..	..	1
	Triartha longiseta	..	..	x	..	..	1
	Rotifera neptunis	..	..	x	..	..	1
	Total Rotifera	..	3	3	..	3	
Protozoa	Ceratium longicorne	x	x	x	x	x	5
	Dinobyron	x	..	..	..	..	1
	Chilomonas sp	..	..	x	..	..	1
	Euglena viridis	..	..	x	..	..	1
	Pleodorina	..	..	x	..	..	1
	Vorticella sp	..	x	..	..	..	1
	Difflugia corona	..	x	..	..	x	2
	Arcella vulgaris	x	x	..	x	..	3
	Total Protozoa	3	4	4	2	2	
Vertebrata	Cyprinus carpio	..	..	..	..	x	1
	Eupomotis gibbosus	..	x	x	..	..	2
	Lepomis pallidus	..	x	x	..	x	3
	Lepomis cyanellus	..	..	x	..	..	1
	Ameiurus natalis	..	..	x	x	..	2
	Ameiurus sp	..	..	..	..	x	1
	Perca flavescens	..	x	x	..	..	2
	Apomotis cyanellus	..	x	..	..	..	1
	Minnows	..	x	..	..	..	1
	Tadpole (Rana)	..	x	x	..	x	3
	Chrysemis marginata	..	..	..	x	x	2
	Sandpiper	x	..	..	..	..	1
	Total Vertebrata	1	6	6	2	5	
Algæ	Merismopedia	..	..	x	..	..	1
	Pediastrum	..	..	x	..	..	1
	Scenedesmus	..	..	x	..	..	1
	Closterium	..	..	..	x	..	1
	Total Algæ	..	..	3	1	..	..
Total species		43	41	39	23	..	50

Turning now to the plankton, the striking feature shown by the quantitative plankton summary, Table 25, page 474, is a progressive diminution in the total number of individuals per hundred liters, as one passes from the youngest to the oldest member of the series. The figures as given include both the phytoplankton and the zooplankton but even exclusive of the phytoplankton the same relative totals exist. As between the youngest and the oldest pond it will be seen that in the one year pond 99 per cent of the total is composed of protozoa and rotifers, while in the thirty year pond entomostraca comprise 85 per cent of the total. In the fifteen year pond entomostraca form a larger percentage of the total although only slightly so. In the ten year pond entomostraca are the most abundant group and are also more numerous than in either of the younger ponds.

The distribution of *Ceratium* throughout the series is most interesting. This protozoan was present in successively and sharply decreasing numbers with increase in the age of the pond. There were enormous numbers of it in the one year pond. In the five year pond there were only one-fourth as many and in the ten year pond there was a sharp decline from this reduced number to scarcely one-fifth of it. This one-fifth was reduced by fifty per cent in the fifteen year pond. In the thirty year pond there was only a trace of Ceratium. Apparently, then, Ceratium found its optimum conditions in the two younger bodies of water. That this condition is a matter of age rather than of distribution or location merely, is borne out by

TABLE 25.
SUMMARY OF QUANTITATIVE PLANKTON RESULTS PER 100 LITERS.

SPECIES	PONDS				
	1 Year	5 Year	10 Year	15 Year	30 Year
Ceratium longicorne	850,000	203,125	11,160	5,250	Trace
Rotifera	4,500	2,231	10,892	5,750	2,000
Arcella vulgaris	4,000	6,250	Few	5,375	Few
Nauplius	15,625	7,500	55,800	Few	2,250
Dinobryon	1,325,000	.....	.....	.....	.....
Cyclops	2,000	.....	.....	.....	.....
Chydorus	.....	6,696	.....	.....	.....
Daphnia	1,500	2,000	.....	.....	.....
Blue-Green algæ	.....	.....	685,250	.....	.....
Pediastrum	.....	.....	17,850	.....	.....
Pleodorina	.....	.....	67,000	.....	.....
Cypris inequivalva	.....	.....	.....	5,890	.....
Cypris sp	.....	.....	.....	6,250	.....
Closterium	.....	.....	.....	535,750	.....
Potamocypris	.....	.....	.....	5,000	1,000
Cyclops ater	.....	1,000	.....	.....	.....
Bosmina longirostris	.....	750	.....	.....	6,300
Scapholebris	.....	.....	.....	.....	1,250
Ophryoxus	.....	.....	.....	.....	2,250
Ceriodaphnia	.....	.....	.....	.....	2,250
Total number of individuals	2,199,125	225,802	847,952	569,265	15,300

the fact that the one, ten and thirty year ponds are within half a mile of each other, whereas the one and five year ponds are five miles apart and in somewhat different surroundings. Furthermore, towings taken at various intervals during the summer for three years, showed that the differences were not merely a matter of pulse.

In general, then, it can be said, regarding the zooplankton, that the percentage of entomostraca increases with age and in the older ponds, forms the greater part of the plankton animals, although the data do not show an absolute increase in numbers. On the other hand, the protozoa and rotifera form the greater part of the zooplankton in the two younger ponds.